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(54) **Sintered carbon brush**

(57) A metal-filled graphite brush used for a miniature electric motor is formed by pressure-forming and sintering a mixture of highly purified graphite powder and metal powder. The graphite powder is purified to reduce the ash content, typically to no more than 0.05 wt.%. The purification treatment usually comprises exposure of the powder to a halogen-liberating substance in a high temperature inert gas atmosphere.

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FIG. 1

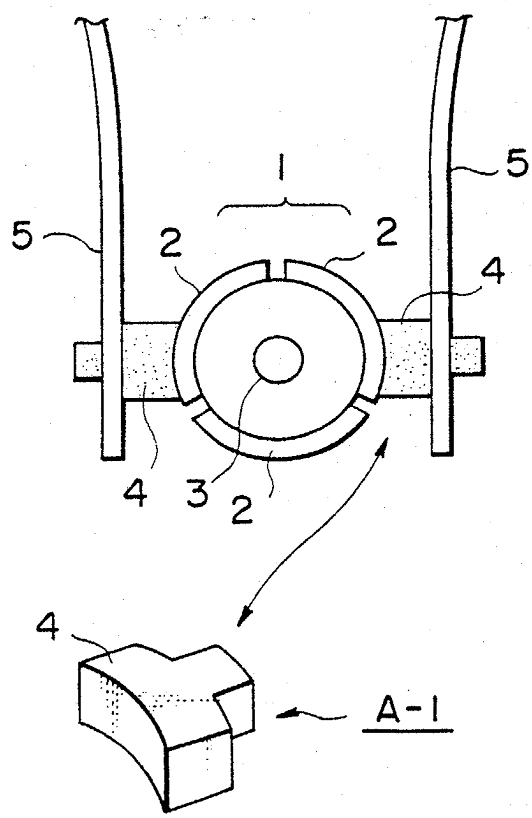


FIG. 2

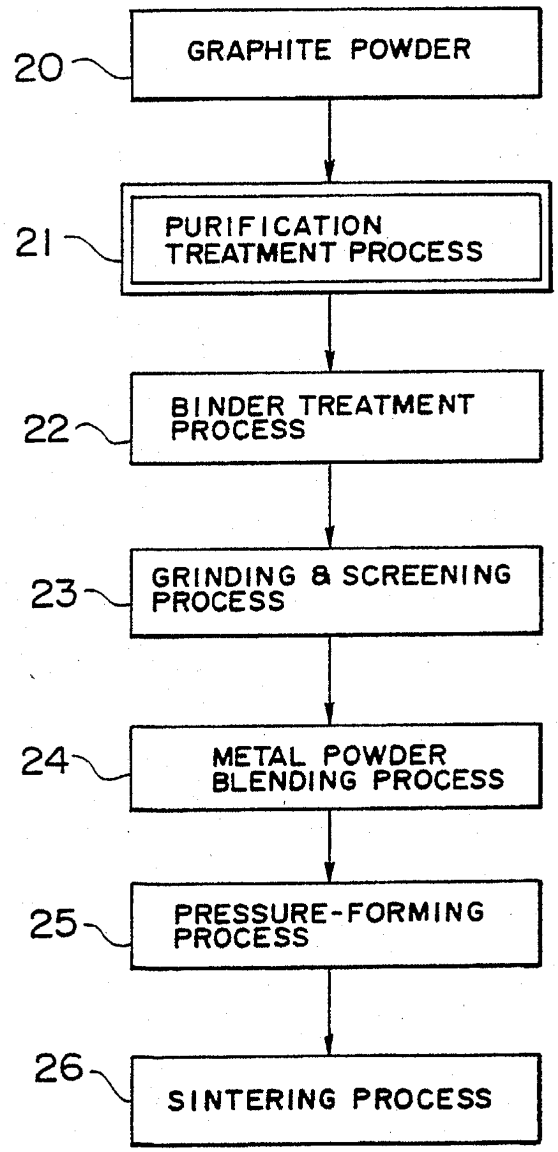

20
GRAPHITE POWDER
21
PURIFICATION TREATMENT PROCESS
22
BINDER TREATMENT PROCESS
23
GRINDING & SCREENING PROCESS
24
METAL POWDER BLENDING PROCESS
25
PRESSURE-FORMING PROCESS
26
SINTERING PROCESS

FIG. 3

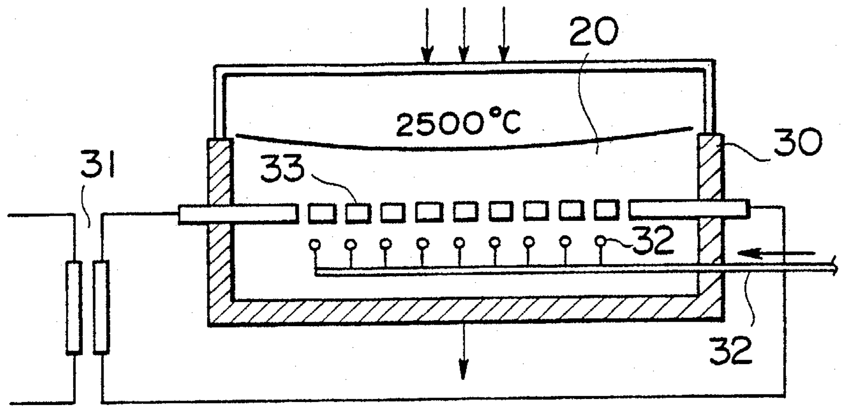


FIG. 4

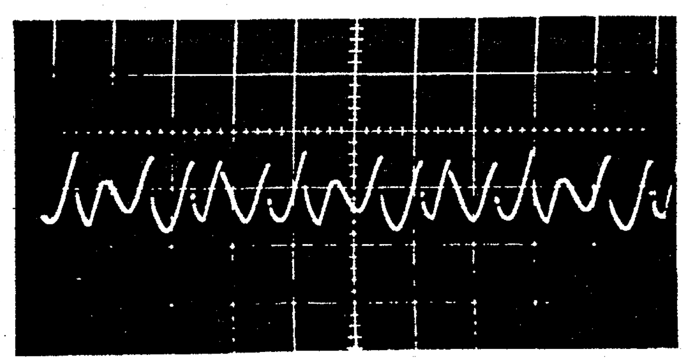


FIG. 5

TEST No.	PARTICLE SIZE OF OXIDE POWDER	SERVICE HOURS TO MOTOR FAILURE (HOURS) 10 20 30 40 50 60 70 80	AVERAGE SERVICE HOURS TO MOTOR FAILURE	DEGREE OF WEAR AFTER 80 HOURS OF MOTOR OPERATION
1	NO ADDITION		OK	100 %
2	LESS THAN 50μ		OK	46 %
3	50μ ~ 60μ		24 HOURS TO MOTOR STOP	41 %
4	60μ ~ 74μ		20 HOURS TO MOTOR STOP	45 %
5	74μ ~ 105μ		3.9h	ALL MOTORS FAILED
6	105μ ~ 149μ		3.2h	〃
7	149μ ~ 174μ		4.3h	〃

FIG.6

TEST No.	WT % OF UNDER-50μ OXIDE POWDER	SERVICE HOURS TO MOTOR FAILURE (HOURS) 10 20 30 40 50 60 70 80	AVERAGE SERVICE HOURS TO MOTOR FAILURE	DEGREE OF WEAR AFTER 80 HOURS OF MOTOR OPERATION
1	0.1		OK	67%
2	0.5		OK	52%
3	1.0		OK	43%
4	3.0		OK	44%
5	5.0		OK	41%
6	10.0		OK	47%
7	12.0		49h	ALL MOTORS FAILED

FIG. 7

TEST No.	TYPE	SERVICE HOURS TO MOTOR FAILURE (HOURS) 10 20 30 40 50 60 70 80	AVERAGE SERVICE HOURS TO MOTOR FAILURE	DEGREE OF WEAR AFTER 80 HOURS OF MOTOR OPERATION
1	NO ADDITION		OK	100%
2	OXIDE POWDER		OK	33%
3	CARBIDE POWDER		OK	19%

FIG. 8

TEST No.	WT % OF UNDER-50μ CARBIDE POWDER	SERVICE HOURS TO MOTOR FAILURE (HOURS) 10 20 30 40 50 60 70 80	AVERAGE SERVICE HOURS TO MOTOR FAILURE	DEGREE OF WEAR AFTER 80 HOURS OF MOTOR OPERATION
1	0.5		OK	32 %
2	1.0		OK	20 %
3	3.0		OK	21 %
4	5.0		OK	20 %
5	10.0		OK	23 %
6	15.0		OK	26 %
7	20.0		67 HOURS	INCREASED WEAR

FIG. 9

TEST No.	PARTICLE SIZE OF CARBIDE POWDER	SERVICE HOURS TO MOTOR FAILURE (HOURS) 10 20 30 40 50 60 70 80	AVERAGE SERVICE HOURS TO MOTOR FAILURE	DEGREE OF WEAR AFTER 80 HOURS OF MOTOR OPERATION
1	LESS THAN 50μ		OK	22%
2	50μ ~ 74μ		OK	20%
3	74μ ~ 105μ		1 MOTOR FAILED AFTER 62 HOURS OF SERVICE	24%
4	105μ ~ 149μ		5 MOTORS FAILED AFTER 53 HOURS OF SERVICE	30%
5	149μ ~ 174μ		38h	INCREASED WEAR

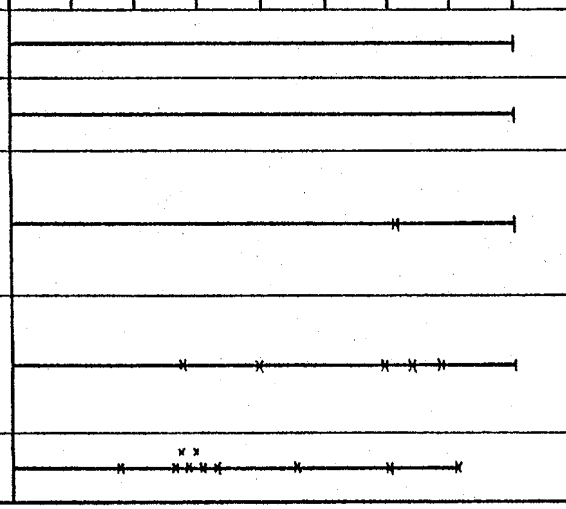


FIG. 10
(PRIOR ART)

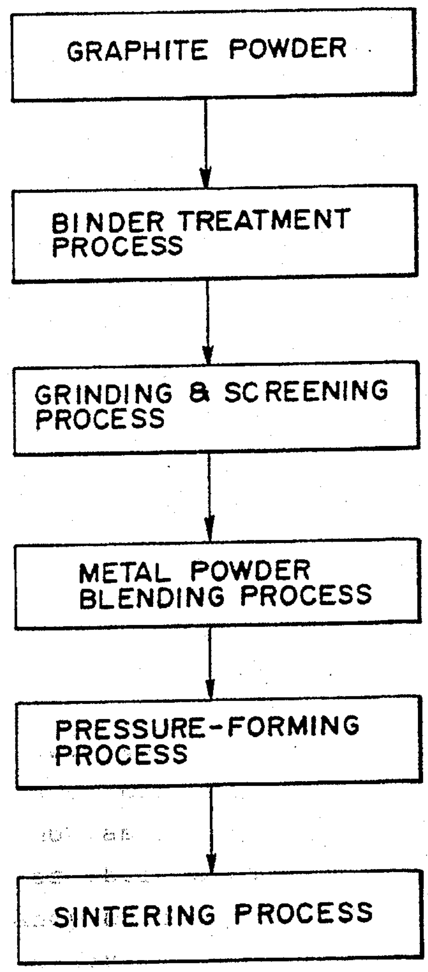
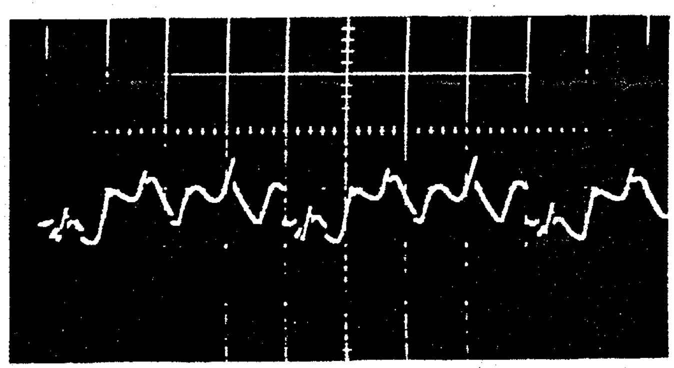


FIG.11
(PRIOR ART)

FIG.12
(PRIOR ART)



CARBON BRUSHES FOR MINIATURE MOTORS

This invention relates generally to carbon brushes for miniature electric motors and the method of making such brushes, particularly for miniature motors having permanent magnetic fields.

Carbon brushes for miniature motors have heretofore been manufactured by adding a binder to graphite powder purified to approximately 98% or 99.5%; grinding and screening the solidified mixture, blending metallic powder with the ground and screened mixture to impart the desired electrical conductivity as necessary, and then pressure-forming and sintering the resulting mixture.

To eliminate the use of the binder, a so-called copper-plated graphite brush is known. The copper-plated graphite brush is manufactured by copper-plating particles of graphite powder which is purified to approximately 99%, then pressure-forming and sintering the copper-plated graphite powder without adding a binder.

According to the present invention, a carbon brush for use in a miniature motor comprises a pressure formed and sintered mixture of metal and graphite powders, the graphite powder having an ash content of no more than 0.05% by weight. The brush can include one or more oxide powders in the mixture, normally up to 10% by weight of the mixture. Other possible additives are wear-resistant and electrically conductive substances such as carbides, nitrides, borides and silicides, normally up to 15% by weight of the mixture. Minimum amounts of any such additive are typically at least 0.1% by weight and maximum particle size typically around 50 microns.

A method according to the invention of manufacturing a carbon brush for a miniature electric motor comprises the sequential steps of:

a) subjecting graphite powder to a purification treatment using a halogen-liberating substance in a high temperature inert gas atmosphere;

b) adding a binder to the purified graphite powder, and grinding and screening a mixture of the purified graphite powder and said binder;

c) blending metal powder with the purified and screened graphite powder;

d) pressure-forming the mixture of said graphite powder and said metal powder into a shaped body; and

e) sintering said pressure formed body.

In methods of the invention where additives are included in the powder mixture, such additives can be introduced at either of steps b) and c).

The invention will now be described by way of example and with reference to the accompanying drawings wherein:

Figure 1 is a diagram illustrating the principle of the invention;

Figure 2 is a flow diagram illustrating one example of the manufacturing method of the invention;

Figure 3 is a conceptual diagram illustrating a refining furnace used in a purification treatment process according to the invention;

Figure 4 is an oscillograph waveform diagram illustrating a commutation waveform for a first metal-filled graphite brush embodying the invention;

Figure 5 shows test result data illustrating the relationship between the particle size of oxide addition and the degree of wear in a second metal-filled graphite brush embodying the invention;

Figure 6 shows test result data illustrating the relationship between the content of oxide addition and the degree of wear in the second carbon brush embodying the invention;

Figure 7 shows test result data for comparing the degree of wear of a third metal-filled graphite brush embodying the invention with the degree of wear of other carbon brushes;

Figure 8 shows test result data illustrating the

relationship between the content of carbide addition and the degree of wear in the third carbon brush embodying the invention;

Figure 9 shows test result data illustrating the relationship between the particle size of carbide addition and the degree of wear in the third carbon brush embodying the invention;

Figure 10 is a flow diagram illustrating the manufacturing process of the metal-filled graphite brush of the prior art;

Figure 11 is a diagram illustrating the composition of the ash content (impurities) of the graphite treated with the manufacturing process of the prior art; and

Figure 12 is an oscillograph waveform diagram illustrating a commutation waveform for the metal-filled graphite brush of the prior art.

Reference will first be made to the prior art illustrated in Figures 10 to 12. Figure 10 illustrates the conventional manufacturing process of carbon brushes for miniature motors, using graphite powder having a purity of 98% to 99.5%. As shown in the Figure, a carbon brush is manufactured by adding a binder to the graphite powder purified to a purity of 98% to 99.5%, grinding and screening the solidified graphite-binder mixture, blending the ground and screened mixture with metal powder to impart desired electrical conductivity, and then pressure-forming and sintering the resulting mixture.

The convention metal-filled graphite brush is manufactured by physically blending natural graphite with a binder, and grinding and screening the mixture. With the physical blending process alone, however, 0.5 to 1.0 wt.% of SiO_2, Al_2O_3, FE_3O_3 silicates, MnO, MgO and other oxides as impurities are left in the graphite in the form of ashes.

Figure 11 is an enlarged view of the ashes (impurities) contained in the graphite.

Even the metal-filled graphite brush manufactured by adding a binder to the graphite powder of the aforementioned purity has good environmental resistance because the amount of the remaining binder is reduced at the time of sintering, and metal particles having a small surface area are less subject to attack by corrosive gases and oxidation.

The carbon brush plated with copper and other metal has a porosity of 10% to 30%. This makes the surface area of the thin-film metal large, leading to high susceptibility to oxidation and attack by corrosive gases.

In this way, the impurities remaining in relatively large quantities tend to damage the lubricating film on the commutator, accelerating the wear of the brush and deteriorating commutation properties.

Figure 12 is an oscillograph waveform for the conventional metal-filled graphite brush. As is evident in the Figure, the waveform of the motor current is considerably irregular. As the wear of the carbon brush proceeds, the insulating material contained in the carbon brush appears on the sliding surface between the brush and the commutator, deteriorating commutation performance, resulting in motor failure in extreme cases.

Figure 1 shows how metal-filled graphite brushes (hereinafter referred to as carbon brushes) are used in a miniature motor, together with a perspective view (A-1) of the carbon brush. In Figure 1, carbon brushes 4 are held by electrically conductive brush resilient members 5 and supported in such a manner as to make sliding contact with segments 2 of a commutator 1 on a rotating shaft 3. The carbon brush 4 is sintered into an inverted T shape with the stem thereof being supported by the brush resilient member 5, as shown in A-1 of Figure 1. The bottom surface of the inverted T shape is formed into a slightly curved shape to make sliding contact with the commutator segment 2.

Figure 2 is a flow diagram illustrating a basic manufacturing process of this invention. A carbon brush is manufactured using graphite powder which is refined to approximately 99% to 99.5%, as shown in Figure 2, by executing the purification treatment process 21, the binder treatment process 22, the pressure-forming process 23 and the sintering process 24 on the graphite powder. Although description of the binder treatment process 22, the pressure-forming process 23 and the sintering process has been omitted because they are well known, the purification treatment process 21, which is a main feature of this invention, will be described in detail, referring to Figure 3.

Figure 3 is a conceptual diagram of a refining furnace used in the purification treatment process. The process corresponds to a process where impurities in graphite powder using a halogen-liberating substance, such as CCl_4 or CCl_2F_2, which readily liberates halogen at high temperatures in an inert gas, such as nitrogen or argon. That is, the graphite powder 20 is charged into the furnace proper 30 in which a halogen gas pipe 32 is placed in the graphite powder 20. As temperature in the furnace is raised by the heater 33 coupled to a power supply transformer 31, to approximately 1800°C, CCl_4 saturated in the inert gas is fed through the halogen pipe 32. In this case, it can be assumed that the following reactions take place in the furnace.

$$CCl_4 - C + 2Cl_2$$

$$3C + Fe_2O_3 + 3Cl_2 \quad - \quad 2FeCl_3 + 3CO$$

When the temperature rises to over 1,900°C, CCl_4 is replaced with Cl_2F_2, and purification treatment is continued for over 4 hours at over 2,500°C. In the subsequent cooling process, flushing with an inert gas, such as nitrogen or argon, is maintained to prevent impurities from reversed diffusion and remove halogen.

This purification treatment process yields graphite having a purity of over 99.95 wt.%, with impurities less than 0.05 wt.%.

Figure 4 is an oscillograph waveform diagram illustrating a commutation waveform for the carbon brush manufactured with the basic manufacturing process shown in Figure 2 (hereinafter referred to as the first carbon brush). In the case of the first carbon brush of this invention, the commutation waveform appears regularly at the time of commutation, as is evident from the oscillograph waveform shown in Figure 4 and unlike the commutation waveform for the prior art carbon brush shown in Figure 12. This suggests that the first carbon brush of this invention has excellent commutation properties.

As described above, a carbon brush having stabilized and excellent commutation properties can be obtained since the carbon brush is manufactured by purifying the graphite powder to a low level of impurities in the purification treatment process in the basic manufacturing process of this invention, blending metal powder with the graphite powder, and pressure-forming and sintering the mixture. Because of the low carbon content of the binder content and the small surface area of the metal powder particles, oxidation is less likely to occur, leading to good environmental resistance.

Tests have been conducted on metal-filled graphite brushes manufactured using the following methods to improve the purity of the graphite:

(i) Physical refining

Graphite was separated from impurities with the flotation process utilizing differences in surface physio-chemical properties of solid particles. The physical refining process handled particles of approximately 300 microns in size. Taking advantage of the fact that graphite can be separated with air bubbles, graphite powder was charged into a mixture of oil and air bubbles, and collected by causing graphite particles to adhere to the floating air bubbles. In this process, purities in the range 98% to 99.5% can be obtained. This means that impurities ranging from 0.5% to approximately 2.0% are contained in the graphite powder.

(ii) Chemical treatment

The impurities contained in graphite were dissolved in high-concentration acid and alkali solutions, and the solutions where heated (to 160°C - 170°C) and pressurized (to 5 - 6 atms). This treatment is commonly called the autoclave process, which mainly consists of the following reactions:

$$Fe_2O_3 + 6HCl - 2FeCl_3 + 3H_2O$$

$$2SiO_2 + 4NaOH - 2Na_2SiO_3 + 2H_2O$$

With this chemical treatment, purities in the range 99% to 99.9% can be obtained, with impurities of up to 1.0% remaining in the graphite powder.

This indicates that the purity of the graphite obtained with the aforementioned physical and chemical refining processes is inferior to the purity of the graphite obtained after the purification treatment process according to this invention. That is, graphite of high purity cannot be obtained with the aforementioned physical and chemical refining.

Next, another embodiment of the carbon brush of this invention (hereinafter referred to as the second carbon brush) and the method of making the second carbon brush will be described. The second carbon brush and the method of making the second carbon brush are essentially the same are as the first carbon brush described earlier, reference to Figures 1 to 4. The second carbon brush has better wear resistance that the first carbon brush. this is made possibly by using oxides (such as SiO_2, Al_2O_3, FE_3O_3, MnO, MgO, TiO, silicates, etc) as wear-resisting substances forcibly adding about 0.1 - 10 wt. % of the oxides of particle sizes less than 50 microns, subjecting the mixture to the binder treatment process and the subsequent processes 23 - 26. Using metal-filled graphite brushed manufactured with these processes, miniature motors having excellent commutation properties and wear resistance can be realized. The aforementioned oxides may be added in the metal powder blending process

24.

Figure 5 shows the test results illustrating the relationship between the range of particle sizes and the degree of wear of the oxides to be added to the binder in the binder treatment process 22 in Figure 2. Figure 6 shows the test results of the degree of wear by changing the oxides content while keeping the particle size of the oxides below 50 microns.

The test results shown in Figures 5 and 6 represent max. 80-hour long operation tests on ten brushes manufactured for each test number. The x mark represents the timing at which a brush failed.

As is evident from Figure 5, the particle size of the oxide powder should be kept under 50 microns (Test No. 2) to reduce wearability. That is, with no oxides added (Test No. 1), wearability becomes higher. With oxides of particle sizes of 50 - 60 microns (Test No. 3), as many as four brushes failed in a relatively short period of time (24 hours on an average). With other particle sizes (Test Nos. 4 through 7), all brushes failed in a short period of time (3.2 - 4.3 hours on an average).

There is no practical problem with the oxide powder content covering a range of 0.1 to 10.0 wt.% (Test No. 1 to Test No. 6) because the degree of wear remains at 41% to 67% in that range, as is evident from Figure 6. With the oxide powder content being as high as 12.0 wt.% (Test No. 7), however, all brushes fail.

On the basis of the aforementioned test results, the second brush of this invention is preferably manufactured by improving commutation properties in a so-called pretreatment process in which the purity of graphite powder is raised to over 99.95% (therefore to under 0.05% of impurities) in the purification treatment process 21 shown in Figure 2, and wear resistance is improved in the binder treatment process 22 in which not only graphite powder is solidified using a binder, as in the prior art, but also 0.1 to 10 wt.% of oxides having

particle sizes less than 50 microns are added to the binder.

Next, another embodiment of the carbon brush of this invention (hereinafter referred to as the third carbon brush) and the method of making the third carbon brush will be described. The third carbon brush and the method of making the same are essentially the same as the first and second carbon brushed noted earlier. The third carbon brush has excellent wear resistance and electrical conductivity compared with the first and second carbon brushes. The third carbon brush is manufactured by adding 0.1 to 15.0 wt.% of wear-resisting and electrically conductive substances (such as carbides consisting chiefly of one or more than two kinds of TiC, ZrC, HfC, VC, NbC, TaC, Cr_3C_2, MoC, WC) of particle sizes less than 50 microns and subjecting the mixture to binder treatment in the binder treatment process 22 in the basic manufacturing process shown in Figure 2 and other subsequent processes 23 - 26. The third carbon brush thus manufactured has good commutation properties and wear resistance as well as electrical conductivity. The aforementioned carbides may be added in the metal powder blending process 24.

Figure 7 shows the results of tests conducted on miniature motors having carbon brushed in which no additives but the binder were added to the graphite powder, which was refined to a purity of 99.96% in the purification treatment process 21 (Test No. 1); carbon brushes manufactured by adding oxides (such as SiO_2, Al_2O_3, FE_3O_3, MnO, MgO, TiO, silicates, etc.) (Test No. 2); and carbon brushes manufactured by adding electrically conductive carbides (Test No. 3).

These tests were conducted by operating miniature motors having the aforementioned carbon brushed for up to 80 hours. In the test, 3 wt.% of the oxides or carbides of particle sizes less than 50 microns were added to the binder in the manufacture of carbon brushes.

As shown in Figure 7, the carbon brushes to which

nothing was added showed 100% of wear, those to which oxides where added showed 33% of wear, and those to which carbides where added showed 19% of wear. This means that the wear resistance of carbon brushes can be increased by adding carbides.

Figure 8 shows the results of tests conducted on carbon brushes to which varied amounts of carbides (of particle sizes less than 50 microns) were added to make clear the changes in wearability with changes in the amount of carbides added. In this case, ten brushes were manufactured by adding varied amounts of carbides and subjected to a max. 80-hours operation texts. The x mark in the Figure represents the timing at which a brush failed.

As shown in the Figure, the carbon brushed to which 0.5 wt.% of carbides were added showed 32% of wear after 80 hours of operation, while those to which 1.0 - 15.0 wt.% of carbides were added showed relatively low wear of 20 - 26%. With 20 wt.% of carbides added, the wear of the commutator became extremely high, so all miniature motors were stopped.

This suggests that the amount of carbide addition should preferably be in the range of 1.0 - 15.0 wt.%.

Figure 9 shows the results of wearability tests on carbon brushes in which the amount of carbide addition was kept constant (3 wt.%) and the particle size thereof was change.

As shown in the Figure, the wearability of the carbon brushes containing carbides of particle sizes less than 50 microns were added was 22% after 80 hours of operation, and the wear of those containing carbides of particle sizes in the range of 50 - 74 microns was 20%. With carbides of particle sizes in the range of 105 - 149 microns, the wear of the carbon brushes was 30%, and the average service hours to motor failure became as short as 53 hours. With particle sizes in the range of 149 - 174 microns, the wear of the carbon brushes sharply increased, with the result that almost all motors failed

increased, with the result that almost all motors failed (average service hours to motor failure: 38 hours).

The optimum particle size and the amount of addition of carbides determined on the basis of the aforementioned test results would seem to be less than 50 microns and within the range of 0.1 - 15.0 wt.%, respectively.

In this embodiment, carbides were used as wear-resisting, electrically conductive substances, but the wear-resisting, electrically conductive substances are not limited to carbides. Similar effects can be achieved by using nitrides (such as TiN, ZrN, NbN, TaN, Cr_2N, VN, etc.), borides (such as TiB_2, ZrB_2, NbB_2, TaB_2, CrB, MoB, WB, LaB, VB_2, etc.), or silicides (such as $TiSi_2$, $ZrSi_2$, $NbSi_2$, $TaSi_2$, $CrSi_2$. $MoSi_2$, WSi_2, etc.).

In addition, similar effects can also be achieved by combining more than two types of the aforementioned carbides, nitrides, borides or silicides.

As described above, the third carbon brush of this invention can realize a metal-filled graphite brush having improved wear resistance and electrical conductivity since the third carbon brush of this invention is manufactured by improving commutation properties in a so-called pretreatment process in which the purity of graphite powder is raised to more than 99.95% (therefore to less that 0.05 wt.% of impurities) in the purification treatment process 21 in Figure 2 prior to the subsequent processes, and improving wear resistance and electrical conductivity in the binder treatment process 22 or the metal powder blending process 24 in which 0.1 to 15.0% of wear-resisting and electrically conductive substances are added to the binder.

CLAIMS

1. A carbon brush for use in a miniature electric motor to conduct current to a commutator on the motor rotor, which brush comprises a pressure formed and sintered mixture of metal and graphite powders, the graphite powder having an ash content of no more than 0.05% by weight.

2. A carbon brush according to Claim 1 including oxide powder in said powder mixture.

3. A carbon brush according to Claim 2 wherein the particle size of the oxide powder is no more than 50 microns.

4. A carbon brush according to Claim 2 or Claim 3 wherein the oxide powder comprises no more than 10% by weight of the powder mixture.

5. A carbon brush according to any of Claims 2 to 4 wherein the oxide powder comprises at least one of SiO_2, Al_2O_3, FE_3O_3, MnO, MgO, TiO and silicates.

6. A carbon brush according to any preceding Claim including wear-resistant and electrically conductive substances in powder form in said powder mixture.

7. A carbon brush according to Claim 6 wherein the particle size of said substances is no more than 50 microns.

8. A carbon brush according to Claim 6 or Claim 7 wherein said substances comprises no more than 15% by weight of the total mixture.

9. A carbon brush according to any of Claims 6 to 8 wherein said substances are carbides.

10. A carbon brush according to Claim 9 wherein said substances comprise at least one of TiC, ZrC, HfC, VC, NbC, TaC, Cr_2C_2, MoC and WC.

11. A carbon brush according to any of Claims 6 to 8 wherein said substances are nitrides.

12. A carbon brush according to Claim 11 wherein said wear-resisting and electrically conductive substances comprise at least one of TiN, ZrN, NbN, TaN,

Cr_2N, VN and WC.

13. A carbon brush according to any of Claims 6 to 8 wherein said substances are borides.

14. A carbon brush according to Claim 13 wherein said substances comprise TiB_2, ZrB_2, NbB_2, Tab_2, CrB, MoB, WB, LaB and VB_2.

15. A carbon brush according to any of Claims 6 to 8 wherein said substances are silicides.

16. A carbon brush according to Claim 15 wherein said substances comprise at least one of $TiSi_2$, $ZrSi_2$, $NbSi_2$, $TaSi_2$, $CrSi_2$. $MoSi_2$ and WSi_2.

17. Carbon brushes for use in a miniature motor substantially as described herein with reference to Figures 1 to 9 of the accompanying drawings.

18. A method of manufacturing a carbon brush for a miniature electric motor comprising the sequential steps of:

a) subjecting graphite powder to a purification treatment using a halogen-liberating substance in a high temperature inert gas atmosphere;

b) adding a binder to the purified graphite powder, and grinding and screening a mixture of the purified graphite powder and said binder;

c) blending metal powder with the purified and screened graphite powder;

d) pressure-forming the mixture of said graphite powder and said metal powder into a shaped body; and

e) sintering said pressure formed body.

19. A method according to Claim 18 including the step of adding oxide powder at one of steps b) and c) in said binder treatment or metal powder blending process.

20. A method according to Claim 18 or 19 including the step of adding a wear-resisting and electrically conductive substance at one of steps b) and C).

21. A method according to any of Claims 18 to 20 wherein the purification treatment comprises heating the graphite powder in a refining furnace and:

a) saturating CCl_4 in an inert gas and feeding the

saturated CCl_4 to the graphite powder as the furnace temperature reaches substantially 1800°C, causing the following chemical reactions:

$$CCl_4 - C + 2Cl_2$$

$$3C + Fe_2O_3 + 3Cl_2 - 2FeCl_3 + 3CO;$$

b) saturating CCl_2F_2 in an inert gas and feeding the saturated CCl_2F_2 in place of CCl_4 to the graphite powder as the furnace temperature exceeds substantially 1900°C;

c) continuing purification with a furnace temperature of at least 2500°C; and

d) cooling the graphite powder while continuing to flush the powder with an inert gas to prevent reversed diffusion of impurities and remove halogen.

22. A method according to Claim 21 wherein the inert gas in any of steps a), b), c), and d) is one of nitrogen and argon.

23. A method according to Claim 18 of manufacturing a carbon brush for a miniature electric motor substantially as herein described.

24. A miniature electric motor including brushes according to any of Claims 1 to 17 or made by a method according to any of Claims 18 to 23.

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